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Declaration

I, Michihiko Matsuba, President of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation, of the copy of Japanese Patent Application No. Hei-11-225974 filed on August 10, 1999.

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[TITLE OF DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION] POLYGON MIRROR, SCANNING OPTICAL SYSTEM, AND ENDOSCOPE APPARATUS

[WHAT IS CLAIMED IS;]

[Claim 1]

A polygon mirror having respective reflection planes formed on positions where respective sides of a prescribed regular prism, which becomes a reference, are turned and displaced centering around respective straight lines perpendicular to the center axis of said regular prism on said respective sides with respect to said respective sides of said corresponding regular prism; and

the center axis of said regular prism is made into a rotation axis.

[Claim 2]

The polygon mirror having respective reflection planes formed on positions where respective sides of a prescribed regular truncated pyramid, which becomes a reference, are turned and displaced centering around respective straight lines perpendicular to the center axis of said regular truncated pyramid on said respective sides with respect to said respective sides of said corresponding regular truncated pyramid; and

the center axis of said regular truncated pyramid is made into a rotation axis.

[Claim 3]

The polygon mirror as set forth in Claim 1 or 2, wherein respective inclination angles formed by said rotation axis and said respective reflection planes differ from each other per reflection plane.

[Claim 4]

The polygon mirror as set forth in Claim 3, wherein a reflection plane adjacent to one side of the minimum angle reflection plane, whose inclination angle is minimized, of said respective reflection planes is disposed so that the inclination angle thereof becomes larger by a prescribed displacement angle than said minimum reflection plane;

and, hereafter, the adjacent reflection planes are, respectively, disposed so that the inclination angles thereof are gradually increased by said displacement angle.

[Claim 5]

A scanning optical system comprising:

a polygon mirror as set forth in any one of Claims 1 through 4;

means for rotatably supporting said polygon mirror;

light incident means, which is fixed with respect to said

supporting means, for guiding light toward said reflection planes of said polygon mirror; and

light emitting means, which is fixed with respect to said supporting means, for emitting light reflected by said reflection planes of said polygon mirror outwards.

[Claim 6]

The scanning optical system as set forth in Claim 5, wherein said light emitting means includes an fθ optical member.

[Claim 7]

An endoscope apparatus comprising:

a first waveguide, a second waveguide and means for optically coupling both said waveguides to each other;

a low coherent light source, disposed at the base end side of one of said first waveguide and said second waveguide, which makes low coherent light incident into said corresponding waveguide;

a scanning portion including a scanning optical system as set forth in Claim 5 or 6, which causes a low coherent light emitted from the tip end of said first waveguide to scan on a prescribed plane of an analyte, and, at the same time, makes low coherent light reflected by said analyte incident into said first waveguide as a measuring beam again;

means for reflecting low coherent light emitted from the tip end of said second waveguide, and making the same into said second waveguide as a reference beam again;

means for relatively varying both an optical path length from said coupling means to said analyte via said first waveguide and an optical path length from said coupling means to said reflecting means via said second waveguide;

an optical detector, disposed at the base end at the other one of said first waveguide and said second waveguide, for detecting coherent light which is produced by coherence of said measuring beam and reference beam as signals; and

means for processing signals, which forms a tomogram image of said analyte on the basis of signals detected from said optical detector while said optical path length varying means relatively varies the optical path length of both said waveguides and simultaneously said scanning portion is scanning using low coherent light.

[Claim 8]

The endoscope apparatus as set forth in Claim 7, wherein said signal processing means forms a tomogram image pertaining to a prescribed three-dimensional area of said analyte, which is provided with the surface and depth direction of said analyte.

[Claim 9]

The endoscope apparatus as set forth in Claim 7 or 8, wherein said optical path length varying means varies the optical path length from said coupling means to said reflecting means via said second waveguide with respect to the optical path length from said coupling means to said analyte via said first waveguide by displacing said reflecting means in the orientation of approaching the tip end of said second waveguide or separating therefrom.

[Claim 10]

The endoscope apparatus as set forth in any one of Claims 7 through 9 wherein said low coherent light source is composed of a super luminance light-emitting diode.

[Claim 11]

The endoscope apparatus as set forth in any one of Claims 7 through 10, further comprising:

an illumination optical system for irradiating visible light or pumping light, which pumps self-fluorescent light of an analyte, to said analyte:

an object optical system for converging light from the surface of said analyte and forming an image of said analyte surface; and

means for picking up the image of said analyte surface,

which is formed by said object optical system.

[Claim 12]

The endoscope apparatus as set forth in Claim 11, further comprising:

a visible light source for emitting visible light;

a pumping light source for emitting pumping light; and

means for changing light sources for making either one of the visible light emitted from said visible light source or pumping light emitted from said pumping light source incident into said illumination optical system;

wherein said object optical system forms an image of an analyte with visible light where said light source changing means makes said visible light incident into said illumination optical system; and

said object optical system forms an image of an analyte with self-fluorescent light where said light source changing means makes said pumping light incident into said illumination optical system.

[Claim 13]

The endoscope apparatus as set forth in Claim 11 or 12, further comprising means for displaying an image of said analyte surface, which is acquired by said pick-up means, and a tomogram image of said analyte formed by said signal

processing means.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Art]

The present invention relates to a polygon mirror for light scanning, a scanning optical system, and an endoscope apparatus capable of picking up tomogram images of an analyte in vivo.

[0002]

[Prior Arts]

Conventionally, an endoscope apparatus for observing the inside of the coelom of a patient has been publicly known. The endoscope apparatus is provided with an endoscope inserted into a coelom of a patient, and a peripheral apparatus connected to the corresponding endoscope and including a light source portion and a processor.

[0003]

The endoscope includes an illumination optical system, connected to a peripheral light source, for illuminating an analyte (coelom wall), an object optical system for forming an image of the analyte, and a CCD disposed in the vicinity of the imaging plane of the corresponding object optical system and connected to a processor of an peripheral apparatus. Also,

the endoscope is provided with a forceps hole for taking out forceps or various types of treating means at the tip end thereof.

[0004]

Using such an endoscope apparatus, an operator is able to observe the inside of a coelom. That is, the operator inserts an endoscope into a coelom of a patient and illuminates the coelom wall by its illumination optical system, whereby an image of the coelom wall is formed on the plane of a CCD by the object optical system. The CCD converts the image into image signals and transmits the same to a processor of a peripheral apparatus. And, the processor of the peripheral apparatus processes the received image signal of the coelom wall and displays the picture of the coelom wall on a monitor display. In this state, the operator is able to observe the inside of the coelom of the patient while looking at the monitor display.

[0005]

If there is a region which is judged to have a possibility of a cancer or tumor, the operator takes out forceps or a biopsy needle through the tip end portion of the endoscope via the forceps hole thereof, and samples tissue of the corresponding region. The tissue thus obtained is subjected to a pathological examination, and a diagnosis is determined on the basis of the

results of the pathological examination.

[0006]

[Problems to be solved by the invention]

According to the prior art endoscope apparatus constructed as described above, since only the surface of the coelom wall of a patient is displayed as an image, a biopsy is required in order to know the state of the tissue under the surface of the coelom wall. In particular, in order to detect an early cancer or small tumor, a biopsy is requisite. However, the pathological examination with respect to the tissue obtained by the biopsy takes much time, wherein there is a problem in that much time is resultantly required for the diagnosis.

[0007]

Further, taking the burden of a patient into consideration, a biopsy is limited to a limited range and a limited number of times. Therefore, there is a possibility that a lesioned part exists at places other than the biopsy region specified by the operator. In such a case, no accurate diagnosis can be expected even depending on the results of the pathological examination.

[0008]

It is therefore an object of the invention to provide

an endoscope apparatus that is able to diagnose in a short time.

[0009]

[Means for Solving the Problems]

The invention employs the following construction in order to solve the above-described problems.

[0010]

That is, a polygon mirror according to the invention is featured in that a polygon mirror has respective reflection planes formed on positions where respective sides of a prescribed regular prism, which becomes a reference, are turned and displaced centering around respective straight lines perpendicular to the center axis of the above-described regular prism on the above-described respective sides with respect to the above-described respective sides of the above-described corresponding regular prism; and the center axis of the above-described regular prism is made into a rotation axis.

[0011]

Further, the polygon mirror may be formed by inclining respective sides of a regular truncated pyramid which becomes a reference, instead of a regular prism. Also, although the polygon mirror has reflection planes of, for example, six through twelve reflection planes, the number of reflection planes may be other than the above.

[0012]

Also, a scanning optical system according to the invention is featured by including the above-described polygon mirror; means for rotatably supporting the above-described polygon mirror; light incident means, which is fixed with respect to the above-described supporting means, for guiding light toward the above-described reflection planes of the above-described polygon mirror; and light emitting means, which is fixed with respect to the above-described supporting means, for emitting light reflected by the above-described reflection planes of the above-described polygon mirror outwards.

[0013]

With such a construction, by reflecting light, which is guided from the incident means, from respective reflection planes and emitting the same from the emitting means one after another in a state where the polygon mirror is rotating centering around the rotation axis thereof, respective scanning lines corresponding to the respective reflection planes of the polygon mirror are formed outward of the emitting means, and the respective scanning lines are juxtaposed with spacing therebetween. And, the respective scanning lines corresponding to the respective reflection planes of the

polygon mirror are caused to cover up a prescribed two-dimensional area. Therefore, the scanning optical system is able to scan the two-dimensional area.

[0014]

In addition, the polygon mirror may be driven and rotated by a motor connected via a pair of bevel gears. Also, worm gears may be employed instead of the bevel gears. Further, the polygon mirror may be directly coupled to a motor and may be driven by the direct drive. In addition, the emitting means may be an fθ optical member having an fθ feature. And, the fθ optical member may be an fθ lens or an fθ mirror.

[0015]

An endoscope apparatus according to the invention is featured in comprising: a first waveguide, a second waveguide and means for optically coupling both the above-described waveguides to each other; a low coherent light source, disposed at the base end side of one of the above-described first waveguide and the above-described second waveguide, which makes low coherent light incident into the above-described corresponding waveguide; a scanning portion including a scanning optical system, which causes a low coherent light emitted from the tip end of the above-described first waveguide to scan on a prescribed plane of an analyte, and, at the same

time, makes low coherent light reflected by the above-described analyte incident into the above-described first waveguide as a measuring beam again; means for reflecting low coherent light emitted from the tip end of the above-described second waveguide, and making the same into the above-described second waveguide as a reference beam again; means for relatively varying both an optical path length from the above-described coupling means to the above-described analyte via the above-described first waveguide and an optical path length from the above-described coupling means to the above-described reflecting means via the above-described second waveguide; an optical detector, disposed at the base end side at the other one of the above-described first waveguide and the above-described second waveguide, for detecting coherent light which is produced by coherence of the above-described measuring beam and reference beam; and means for processing signals, which forms a tomogram image of the above-described analyte on the basis of signals detected from the above-described optical detector while the above-described optical path length varying means relatively varies the optical path length of both the above-described waveguides and simultaneously the above-described scanning portion is scanning using low coherent light.

[0016]

With such a construction, low coherent light emitted from the low coherent light source is divided into two by the coupling means, one of which is guided to the first waveguide, and the other of which is guided to the second waveguide. And, the low coherent light emitted from the first waveguide is caused to scan a prescribed two-dimensional area on an analyte by being emitted to the analyte by the scanning portion. The low coherent light reflected by the analyte is made incident into the first waveguide as a measuring beam again. On the other hand, the coherent light bifurcated by the coupling means and led to the second waveguide is emitted from the second waveguide and is reflected by the reflecting means. The low coherent light reflected by the reflecting means is made incident into the second waveguide as a reference beam again. The measuring beam and reference beam are caused to cohere with each other and become coherent light, which is detected by an optical detector as signals. At this time, since the optical path length varying means varies the optical path length, the signal processing means is able to form a tomogram image pertaining to a three-dimensional area consisting of the two-dimensional area of the analyte and area from the surface of the corresponding analyte to a prescribed depth.

[0017]

The low coherent light source may be a super luminance light-emitting diode. And, the low coherent light source may be disposed at the base end side of the first waveguide, and the optical detector may be disposed at the base end side of the second waveguide. Instead, the low coherent light source may be disposed at the base end side of the second waveguide, and the optical detector may be disposed at the base end side of the first waveguide.

[0018]

Also, after scanning in the depth direction is carried out with respect to a certain scanning point on the surface of the analyte, scanning in the depth direction may be carried out with respect to a next scanning point. Instead, first, two-dimensional scanning roughly parallel to the surface of the analyte is finished in a state where the scanning position in the depth direction is fixed, and next, two-dimensional scanning may be carried out again with the scanning position in the depth direction changed.

[0019]

Also, both the waveguides may be, respectively, composed of one single-mode optical fiber. Further, the coupling means may be an optical fiber coupler or a beam splitter prism.

Further, both the waveguides and coupling means may include a feature of holding a polarization plane.

[0020]

The above-described optical path length varying means varies the optical path length from the above-described coupling means to the above-described reflecting means via the above-described second waveguide with respect to the optical path length from the above-described coupling means to the above-described analyte via the above-described first waveguide by displacing the above-described reflecting means in the orientation of approaching the tip end of the above-described second waveguide or separating therefrom. Herein, a piezo element may be used as a mechanism for driving the reflecting means. Instead, a voice coil motor or a servomotor may be used.

[0021]

In addition, the optical path length varying means may vary the optical path length from the coupling means to the analyte via the first waveguide in a state where the reflecting means is fixed. Also, the reflecting means may be composed of a reference mirror or a corner cube, etc.

[0022]

In addition, the endoscope apparatus may be composed so

as to enable normal observation or fluorescent observation.

[0023]

Also, the displaying means may be a CRT, liquid crystal display or plasma display, etc.

[0024]

[Preferred Embodiment of the Invention]

Hereinafter, a description is given of one embodiment of the invention on the basis of the accompanying drawings.

[0025]

An endoscope apparatus according to the present embodiment includes an endoscope 1, a peripheral apparatus 2 connected to the endoscope 1, a monitor (displaying means) 3 connected to the corresponding peripheral apparatus 2, and an input unit 4. Fig. 1 is a brief configurational view of the endoscope apparatus.

[0026]

First, a description is given of the construction of the endoscope 1. The endoscope 1 includes an operation portion that is provided with a slender and roughly cylindrical insertion portion (not illustrated) inserted into vivo and various types of operation switches (not illustrated) connected to the base end side of the corresponding insertion portion.

[0027]

An illumination optical system 12, an object optical system 13, a CCD 14 acting as pick-up means, and an OCT scanning portion 15 are disposed in the insertion portion of the endoscope 1. The illumination optical system 12 is provided with a light distribution lens 12a fitted to the tip end of the insertion portion, and a light guide fiber handle 12b (hereinafter called a "light guide") that is disposed opposite to the light distribution lens 12a at the tip end side, inserted through the endoscope 1, and connected to the peripheral apparatus 2 at the base end side.

[0028]

The object optical system 13 includes an object lens (not illustrated) fitted to the tip end of the insertion portion and a cut-off filter that interrupts ultraviolet rays. And, the object optical system 13 converges an incident object light on the pick-up plane of the CCD 14 and forms an image of the object (coelom wall that is an analyte). Also, the CCD 14 acquires image signals of the object image formed on the pick-up plane. In addition, the CCD 14 is connected to the peripheral apparatus 2 via a signal line 14a and transmits the acquired image signals to the peripheral apparatus 2.

[0029]

Further, a description is later given of the construction

of the OCT scanning portion 15.

[0030]

The endoscope 1 thus constructed is connected to the peripheral apparatus 2. Hereinafter, a description is given of the construction of the peripheral apparatus 2. The peripheral apparatus 2 includes a light source portion 21, a processor 22, and an OCT portion 23 as shown in Fig. 1.

[0031]

First, the light source portion 21 is described. The light source portion 21 includes a white light source 211 acting as a visible light source for emitting white light (visible light) and a pumping light source 212 for emitting pumping light. Also, the pumping light is ultraviolet through blue light whose wavelength band is approx. 350 through 400nm, and excites self-fluorescent light (approx. 420nm through 600nm) of the organism tissue.

[0032]

A collimate lens La, a changeover mirror 213, an aperture 215, a condenser lens Lc, and a rotary filter C are disposed in order on the optical path of white light emitted from the white light source 211. The changeover mirror 213 is coupled to a light source changeover controlling mechanism 214, and the changeover mirror 213 and light source changeover

controlling mechanism 214 function as means for changing the light sources. That is, the light source changeover controlling mechanism 214 is disposed at either one of the position where the changeover mirror 213 is retreated from the optical path of white light in order to permit the white light to pass therethrough or the position where the white light is interrupted.

[0033]

In addition, the aperture 215 is coupled to an aperture controlling mechanism (not illustrated). The aperture controlling mechanism is able to adjust the light intensity of the illumination light by controlling the aperture 215. The rotary filter C has a circular shape at its outer profile, and includes four types of filters that are formed to be fan-shaped with equal angles therebetween, that is, three color filters of B (Blue), G(Green), R(Red), and a transparent filter. And, the rotary filter C is coupled to a rotary filter controlling mechanism 216. The rotary filter controlling mechanism 216 is able to insert the respective color filters of B, G and R and transparent filter in the optical path (in the order of B → G → R → Transparent) by rotating the rotary filter C.

[0034]

When the white light source 211 emits white light toward

the collimate lens La, the emitted white light is converted to parallel light by the collimate lens La. At this time, if the changeover mirror 213 is disposed at the position where white light is permitted to pass through, the white light is able to be oriented to the aperture 215. The white light whose light intensity is adjusted by the aperture 215 is condensed by the condenser lens Lc and passes through the rotary filter C. Herein, the rotary filter C is driven and rotated by the rotary filter controlling mechanism 216, wherein the respective color filters of B, G and R and transparent filter are inserted into the optical path one after another. Therefore, the white light is gradually turned into B light, G light, R light and white light, and is made incident into the base end plane of the light guide 12b.

[0035]

On the other hand, the collimate lens Lb and prism P are disposed in order on the optical path of the pumping light emitted from the pumping light source 212. The pumping light from the pumping light source 212 is reflected by the prism P after being converted to parallel light by the collimate lens Lb, and is oriented toward the changeover mirror 213. And, the changeover mirror 213 reflects the pumping light toward the aperture 215 in a state where the changeover mirror 213 is

disposed at the position of interrupting white light. The pumping light reflected by the changeover mirror 213 is condensed by the condenser lens Lc after the light intensity thereof is adjusted by the aperture 215, and is oriented toward the rotary filter C. Herein, the rotary filter controlling mechanism 216 fixes the rotary filter C in a state where the transparent filter thereof is inserted into the optical path, whereby the pumping light passes through the transparent filter of the rotary filter C and is made incident into the base end plane of the light guide 12b.

[0036]

That is, the change over mirror 213 is brought into a normal observation state where only white light from the white light source 211 is introduced to the aperture 215 or a fluorescent observation state where only the pumping light from the pumping light source 212 is introduced to the aperture 215. Also, the rotary filter C is brought into a normal observation state where the respective filters are inserted into the optical path one after another by causing the rotary filter to rotate and the incident white light is gradually emitted as B light, G light, R light and white light or a fluorescent observation state where the transparent filter is fixed as it is inserted into the optical path.

[0037]

Next, a description is given of the processor 22. The processor 22 includes a CPU 221 and a timing generator 222. The CPU 221 is connected to the light source changeover controlling mechanism 214 of the light source portion 21, rotary filter controlling mechanism 216 and aperture controlling mechanism, timing generator 222 and input unit 4, respectively. The timing generator 222 generates various types of reference signals, wherein various processes in the corresponding processor 22 and various processes in the OCT portion 23 described later are advanced by the reference signals.

[0038]

And, the CPU 221 is able to change the changeover mirror 213 to a normal observation state or fluorescent observation state by controlling the light source changeover controlling mechanism 214 and change the rotary filter C to the normal observation state or fluorescent observation state by controlling the rotary filter controlling mechanism 216. That is, the operation portion (not illustrated) of the endoscope 1 is provided with a switch (not illustrated) that designates the normal observation state or the fluorescent observation state. The CPU 221 establishes both the changeover mirror 213

and rotary filter C to the state, designated by the switch of the above-described operation portion, of the normal observation state and the fluorescent observation state by detecting a state of the switch and controlling the light source changeover controlling mechanism 214 and rotary filter controlling mechanism 216. Further, the CPU 211 controls the process in the corresponding processor 22 and the process in the OCT portion 23 described later via the timing generator 222.

[0039]

Further, the processor 22 includes an initial stage signal processing circuit 223, an RGB memory 224, a picture signal processing circuit 225, which are connected to the CCD 14 of the endoscope 1 via the signal line 14a, and a video capture unit 226 connected to the monitor 3. In addition, the initial stage signal processing circuit 223, RGB memory 224, picture signal processing circuit 225 and video capture unit 226 are connected to the timing generator 222 via a signal line (not illustrated).

[0040]

Where the changeover mirror 213 and rotary filter C are established at the normal observation state, the initial stage signal processing circuit 223 holds only the image signals,

acquired when B light, G light or R light is emitted from the light distribution lens 12a of the illumination optical system 12, of the image signals transmitted from the CCD 14, and abolishes the image signals acquired when white light is emitted. And, the initial stage signal processing circuit 223 analog-digitally converts respective image signals, when B light, G light and R light are emitted, after the signal processing is completed, and stores the converted data in respective areas of B, G and R in the RGB memory 224, respectively.

[0041]

Also, where the changeover mirror 213 and rotary filter C are established at the fluorescent observation state, the initial stage signal processing circuit 223 holds image signals transmitted from the CCD 14, and analog-digitally converts the same after the signal processing is completed, and simultaneously stores the converted data in all the areas of B, G and R in the RGB memory 224. (That is, the converted data are processed in a state of monochrome).

[0042]

The picture signal processing circuit 225 generates picture signals by acquiring and processing data stored in the RGB memory 224 at a prescribed timing, and transmits the picture

signals to the video capture unit 226. The video capture unit 226 displays the acquired picture signals on the monitor 3.

[0043]

In addition, the processor 22 includes the OCT initial stage signal processing circuit 227, OCT memory 228, and OCT picture signal processing circuit 229, which are connected to the OCT portion 23 described later. The OCT initial stage signal processing circuit 227 acting as signal processing means analog-digitally converts the signals transmitted from the OCT portion 23 as described later, and stores the same in the OCT memory 228. The OCT picture signal processing circuit 229 generates picture signals by acquiring and processing the data in the OCT memory 228 at a prescribed timing, and transmits the picture signals to the video capture unit 226. The video capture unit 226 displays the acquired picture signals on the monitor 3.

[0044]

Next, a description is given of the OCT portion 23. Fig. 2 is an exemplary view showing the optical path of the OCT portion 23. The following description is based on the drawing. The OCT portion 23 that acquires a tomogram below the surface of a coelom cavity wall by OCT (Optical Coherence Tomography) is provided with a super luminance light-emitting diode 231

(hereinafter called an "SLD"), an optical detector element 232, a reference mirror 233, a mirror drive mechanism 234, and a scanning control circuit 235.

[0045]

The SLD 231 is a light source that emits low coherent light in a near-infrared zone. The coherence length of light emitted from the SLD 231 is in the order of, for example, 10 through 1000μm, and is very short. In addition, the optical detector 232 is composed of a photo diode, and is connected to the OCT initial stage signal processing circuit 227 of the processor 22.

[0046]

The mirror drive mechanism 234 acting as the optical path length varying means displaces the reference mirror 233, which acts as reflecting means as described later, at a high speed, and is connected to the timing generator 222 of the processor 22. Also, the scanning controlling circuit 235 is connected to the OCT scanning portion 15 of the endoscope 1, and at the same time, is connected to the timing generator 222 of the processor 22.

[0047]

Further, the OCT portion 23 includes the first optical fiber F1, second optical fiber F2, optical coupler 238, and

a piezo modulator element 239. Also, the optical fibers F1 and F2 are, respectively, composed of a single mode optical fiber. And, the optical coupler 238 is composed of an optical fiber coupler.

[0048]

The first optical fiber F1 acting as the first waveguide is disposed so that the base end side thereof is opposed to the SLD 231, and is simultaneously passed through the endoscope 1, and the tip end side thereof is opposed to the OCT scanning portion 15 in the endoscope 1. Also, the second optical fiber F2 acting as the second waveguide is disposed so that the base end side thereof is opposed to the optical detector 232, and at the same, the tip end side thereof is opposed to the reference mirror 233. In addition, the reference mirror 233 is driven by the mirror drive mechanism 234 and is able to be reciprocatingly displaced in the axial direction of the second optical fiber F2.

[0049]

And, the optical fibers F1 and F2 are optically coupled to each other by the optical coupler 238. Also, the optical path length from the optical coupler 238 to the tip end in the first optical fiber F1 and the optical path length from the optical coupler 238 to the tip end in the second optical fiber

F2 are established to be identical to each other. Further, the first optical fiber F1 is wound on the circumferential surface of the circular-shaped piezo modulating element 239 at a prescribed position between the optical coupler 238 and the tip end. The piezo modulating element 239 repeats extension and contraction in the diametrical direction at a high speed, and is able to modulate the frequency and phase of light passing through the wound optical fiber F1.

[0050]

Also, the SLD 231, optical detector 232, reference mirror 233, both optical fibers F1 and F2, and optical coupler 238 configure as a Michelson interferometer by being disposed as described above.

[0051]

And, the OCT portion 23 is able to pick up a tomogram of an analyte (coelom wall) in a state where the tip end portion of the insertion portion in the endoscope 1 is opposed to the analyte. Hereinafter, a description is given of the principle of picking up a tomogram.

[0052]

Low coherent light emitted from the SLD 231 is made incident into the first optical fiber F1 and is divided into two by the optical coupler 238, wherein the divided beams are,

respectively, oriented toward the tip end sides in the first optical fiber F1 and the second optical fiber F2. The light in the first optical fiber F1 is polarized in the OCT scanning portion 15 of the endoscope 1 as described later and is emitted outside the endoscope 1. The emitted light is reflected by the surface of coelom wall and tissues of various depths in the vicinity of the surface. The reflected light is made incident into the endoscope 1 and is further made incident into the optical fiber F1 through the OCT scanning portion 15. Finally, the light is oriented to the optical coupler 238 as a measuring beam.

[0053]

On the other hand, the light that is divided into two by the optical coupler 238 and is made incident into the second optical fiber F2 is emitted from the tip end thereof and reflected by the reference mirror 233. The light reflected by the reference mirror 233 is made incident into the second optical fiber F2 again, and is oriented to the optical coupler 238 as a reference beam.

[0054]

The measuring beam in the first optical fiber F1 and reference beam in the second optical fiber F2 are caused to interfere with each other in the optical coupler 238. However,

since the measuring beam is reflected by respective layers of the tissues that constitute the coelom wall, it is made incident into the optical coupler 238 with some range in terms of time. That is, the light reflected by the surface of the coelom wall arrives at the optical coupler 238 much earlier, and the light reflected by a layer deeper than the surface arrives at the optical coupler 238 with some delay.

[0055]

However, since the reference light is reflected by the reference mirror 233, the light is made incident into the optical coupler 238 with almost no range in terms of time. Therefore, light, which actually coheres with the reference light, of the measuring beam is only the light passing through the same optical path length as that from the optical coupler 238 to the reference mirror 233 via the second optical fiber F2. That is, only the light, which is reflected on a layer at a certain depth below the surface of the coelom wall, of the measuring beam is caused to cohere with the reference light.

[0056]

The light (coherent light) cohered in the optical coupler 238 advances to the base end side in the optical fiber F2, and will be detected by the optical detector 232. Therefore, if the mirror drive mechanism 234 displaces the position of the

reference mirror 233, the optical path length at the reference beam side may change, wherein the depth of the measuring position at the coelom wall is accordingly displaced.

[0057]

Also, since the intensity of reflected light differs in response to the state of the tissue below the surface of the coelom wall, a tomogram can be obtained on the basis of the distribution of the intensity of the reflected light from the surface of the coelom wall surface to a prescribed depth.

[0058]

Also, the optical detector 232 outputs coherent light as a signal as described above, and outputs non-cohered light as low-level noise. However, if the S/N ratio between the signal and noise is lower, it is impossible to extract highly accurate signals. Accordingly, in order to increase the S/N ratio, the optical heterodyne detection method is utilized. That is, with respect to the light passing through the first optical fiber F1, the frequency and phase thereof are modulated by the piezo modulating element 239. If so, since the frequency and phase of the measuring beam and reference beam slightly shift, humming is generated by the coherent light. Therefore, if the optical detector 232 receives the coherent light of this state, a beat signal is outputted from the corresponding optical

detector 232.

[0059]

And, the OCT initial stage signal processing circuit 227 of the processor 22 is able to extract signal components highly accurately by demodulating the beat signal outputted from the optical detector 232. Also, the OCT initial stage signal processing circuit 227 further analog-digitally converts the demodulated signal and stores the same in the OCT memory 228.

[0060]

In addition, in reality, a tomogram is obtained by sweeping in the depth direction per scanning point with respect to a plurality of scanning points hypothetically disposed on a coelom wall. Therefore, it is necessary to move the position on the coelom wall, which is irradiated by low coherent light emitted from the first optical fiber F1, in a prescribed area. The OCT scanning portion 15 according to the embodiment is able to move the position of irradiation of low coherent light in a prescribed plane on the coelom wall. Hereinafter, with reference to Fig. 3, Fig. 4 and Fig. 5, a detailed description is given of the OCT scanning portion 15.

[0061]

Fig. 3 is a sectional view taken by cutting the tip end of the endoscope 1 along the plane parallel to the center axis

thereof. Fig. 4 is a cross-sectional view taken along the line IV-IV of Fig. 3, and Fig. 5 is a view obtained by observing Fig. 3 in the V direction. The insertion portion of the endoscope 1 has a roughly columnar casing 11 at the tip end thereof. In addition, in Fig. 3, only the outer portion of the casing 11 is illustrated in terms of its pattern. The illustration thereof is omitted in Fig. 5.

[0062]

Further, the circumferential portion at the tip end plane of the casing 11 is chamfered to be smooth. The OCT scanning portion 15 is housed in the vicinity of the tip end in the casing 11. That is, the casing 11 functions as means for supporting the OCT scanning portion 15 that acts as the scanning optical system. And, the first optical fiber F1 of the OCT portion 23 is disposed so that it is passed through the endoscope 1 and the tip end portion thereof is opposed to the OCT scanning portion 15.

[0063]

The OCT scanning portion 15 includes a collimate lens 151, a polygon mirror 152, and an fθ lens 153, which acts as an fθ optical member, in order on the optical path.

[0064]

The collimate lens 151 has a shape equivalent to such

that a rotation-symmetrical plano-convex lens is chamfered by an edge forming a regular prism coaxial with the optical axis thereof. The collimate lens 151 is disposed so that the focus at the side of a plane having power is made coincident with the emission end plane of the optical fiber F1, and the optical axis is made coaxial with the axis of the optical fiber F1. Therefore, the collimate lens 151 converts light emitted from the optical fiber F1 to parallel light. In addition, the collimate lens 151 functions as incident means for guiding the light emitted from the optical fiber F1 to the inside of the corresponding OCT scanning portion 15.

[0065]

The polygon mirror 152 is like a hexagonal prism, and the respective sides thereof are formed to be reflection planes Mn (n is plane number, n=1, 2, ... 6). Also, the shape of the polygon mirror 152 will be described in detail later. And, the polygon mirror 152 is rotatably supported around the center axis (rotation axis) thereof, and the rotation axis is perpendicular with respect to the center axis of the casing 11. In addition, a bevel gear 155 is fixed at one end side of the rotation axis of the polygon mirror 152. The bevel gear 155 is engaged with another bevel gear 156 which is fixed at a drive shaft 157 parallel to the center axis of the casing

11. Further, the drive shaft 157 is coupled to a scanning motor (not illustrated).

[0066]

The fθ lens 153 has a shape equivalent to such that a rotation-symmetrical plano-convex lens having an fθ feature is chamfered by an edge plane having a regular prism coaxial with the optical axis. The fθ lens 153 is disposed so that a wider pair of sides of respective pairs (two pairs in total) opposed to each other are oriented perpendicular to the rotation axis of the polygon mirror 152, and the plane perpendicular to the optical axis is opposed to the polygon mirror 152, and at the same time, oriented to be parallel to the center axis of the casing 11. Also, the fθ lens 153 forms an afocal optical system together with the collimate lens 151. And, the fθ lens 153 converges the parallel light reflected by the polygon mirror 152 outward of the endoscope 1. Also, fθ lens 153 functions as means for emitting the light reflected by the polygon mirror 152 outwards of the endoscope 1.

[0067]

Next, a detailed description is given of the construction of the polygon mirror 152 in the above-described OCT scanning portion 15. A normal polygon mirror is prism-shaped like a hexagonal prism, and is designed so that respective sides of

the corresponding prism, respectively, become reflection planes. However, in reality, plane inclination will result from the working accuracy in production. The plane inclination means that the actual reflection plane is not made coincident with the position of the reflection plane in design, and is inclined with respect thereto. Usually, the plane inclination is suppressed to be 0.01° or so.

[0068]

On the polygon mirror 152 according to the embodiment, the respective reflection planes Mn are formed so as to be inclined by inherent angles with respect to the sides of the hexagonal prism that becomes the reference. Although the normally unavoidable plane inclination is in the order of "seconds," the reflection planes of the polygon mirror 152 according to the embodiment are designed in advance by being inclined in the order of "degrees."

[0069]

Fig. 6 is a view showing the profile of the polygon mirror 152. In the drawing, hexagonal prism H being a regular prism, which becomes the reference, and reflection plane Mn are shown. The reflection plane Mn is made to agree with the plane that is obtained by being rotated and displaced by a prescribed angle (inclination angle) ξn around an axis R perpendicular to the

center axis of a hexagonal prism H on a reference side plane where the side of the hexagonal prism H is made into the reference side plane. Also, the values of ξn differ from each other per plane (n=1, 2, ... 6).

[0070]

Here, it is assumed that the up and down relationship in Fig. 6 is the same as that in Fig. 5. Herein, as shown in Fig. 6, where the upper side of the reflection plane Mn is located outside the reference side plane of the hexagonal prism H, and at the same time, the lower side of the reflection plane Mn is located inside the reference side plane of the hexagonal prism H, the code of ξn is made positive. On the contrary, where the upper side of the reflection plane Mn is located inside the reference side plane of the hexagonal prism H, and at the same time, the lower side of the reflection plane Mn is located outside the reference side plane of the hexagonal prism H, the code of ξn is made negative.

[0071]

Fig. 7 is a view showing the values of the respective inclination angles ξn per reflection plane Mn. As shown in Fig. 7, the values of the respective inclination angles per reflection plane Mn are M1: $\xi 1 = -2.5°$, M2: $\xi 2 = -1.5°$, M3: $\xi 3 = -0.5°$, M4: $\xi 4 = +0.5°$, M5: $\xi 5 = +1.5°$, M6: $\xi 6 = +2.5°$.

[0072]

In the OCT scanning portion 15 thus constructed, light emitted from the optical fiber F1 is converted to parallel light by the collimate lens 151 and is oriented to the polygon mirror 152. And, light reflected by either of the reflection planes Mn of the polygon mirror 152 is condensed by the fθ lens 153 and is caused to converge outward of the endoscope 1.

[0073]

Here, a scanning motor (not illustrated) rotates the drive shaft 157 at an equal speed and also rotates the polygon mirror 152 at an equal speed via both bevel gears 155 and 156. Therefore, light reflected by the respective reflection planes of the polygon mirror 152 scans above the coelom wall outward of the endoscope 1 via the fθ lens 153. Also, during scanning by one reflection plane Mn of the polygon mirror 152, the loci of light that irradiates above the coelom wall become scanning lines.

[0074]

However, the respective reflection planes Mn of the polygon mirror 152 according to the embodiment are inclined by respective inherent inclination angles ξn with respect to the center axis of the hexagonal prism H that becomes the reference. For this reason, a scanning line formed by scanning

with respect to one reflection plane Mn of the polygon mirror 152 and a scanning line formed by the next reflection plane Mn are caused to shift in a state parallel to each other. That is, the respective scanning lines formed in the direction perpendicular to the page of Fig. 4 shift in the left and right directions in Fig. 4. Herein, the larger the value ξn is, the further the scanning line corresponding thereto shifts to the right side in Fig. 4.

[0075]

And, since the polygon mirror 152 rotates counterclockwise in Fig. 3, the respective reflection planes Mn of the polygon mirror 152 cause the light, which is emitted from the collimate lens 151, to scan. Therefore, the respective reflection planes Mn are subjected to scanning in the order of the plane number (M1→M2→M3→M4→M5→M6), wherein the corresponding scanning lines shift from left to right in Fig. 4. And, as soon as the scanning is terminated by the reflection plane M6, scanning is started again by the reflection plane M1. At this time, the scanning line returns to the left side position in Fig. 4. Therefore, in a plane which is roughly parallel to the surface of the coelom wall, a roughly rectangular area whose longer sides are the scanning line made by the reflection plane M1 and the scanning line made by the

reflection plane M6 is hypothetically covered up by the respective scanning lines made by the respective reflection planes Mn.

[0076]

Also, as shown in Fig. 7, the inclination angle ξn is stepwise increased by a prescribed displacement angle (1.0°) from the reflection plane M1 of the polygon mirror 152 to the reflection plane M6 thereof. Therefore, the fθ lens 153 is caused to arrange the respective scanning lines, which are hypothetically formed by the light reflected by the respective reflection planes Mn, equidistantly on the coelom wall. And, two-dimensional scanning is carried out by sweeping six scanning lines, which are equidistantly juxtaposed as shown above, one after another.

[0077]

The light reflected by the coelom wall is made incident into the endoscope 1 in the inverted course as a measuring beam. That is, the measuring beam is made incident into the optical fiber F1 by passing through the fθ lens 153, polygon mirror 152, and collimate lens 151 in this order.

[0078]

The mirror drive mechanism 234 of the OCT portion 23 in the peripheral apparatus 2 reciprocates the reference mirror

233 in the direction parallel to the optical fiber F2 at a high speed. That is, the reference mirror 234 makes a reciprocation at a high speed at every instant when the polygon mirror 152 is considered to stop, whereby, at a certain scanning point on a certain scanning line, an area from the surface of the coelom wall of the corresponding scanning point to a prescribed depth (for example, 2mm) that becomes an object to be measured is swept.

[0079]

With respect to all the scanning points hypothetically arrayed on a certain scanning line equidistantly, sweeping in the depth direction is carried out by repeating the above-described process. Further, with respect to all the scanning points in a prescribed rectangular area, the sweeping in the depth direction is completed by repeating the process with respect to the subsequent scanning lines one after another.

[0080]

Also, although not illustrated, a light distribution lens 12a of the illustration optical system 12 and an object lens (not illustrated) of the object optical system 13 are fitted in the vicinity (at the base end side) of the fθ lens 153 at the side of the casing 11.

[0081]

A description is given of operations of an endoscope apparatus according to the embodiment constructed as described above. First, when an operator turns on the power source of the peripheral apparatus 2, the white light source 211 and pumping light source 212 are turned on. Also, the changeover mirror 213 and rotary filter C are set to the normal observation state in the default status. Therefore, only the while light from the white light source 211 reaches the aperture 215 and condenser lens Lc.

[0082]

Herein, since the rotary filter controlling mechanism 216 inserts respective filters of the rotary filter C into an optical path one after another, the white light emitted from the condenser lens Lc is made into B light, G light, R light and white light one after another, and is converged at the based end plane of the light guide 12b. The light that entered the light guide 12b is caused to advance by being guided by the corresponding light guide 12b and is emitted from the light distribution lens 12a. That is, respective illumination beams of B light, G light, R light and white light are emitted from the light distribution lens 12a one after another.

[0083]

And, where the operator inserts the insertion portion

11 of the endoscope 1 into the coelom of a patient, and the light distribution lens 12a of the illumination optical system 12, object lens 13a of the object optical system 13, and fθ lens 153 of the OCT scanning portion 15 are disposed opposite to the coelom wall that becomes an object to be observed, respective illumination beams emitted from the light distribution lens 12a are caused to irradiate the coelom wall one after another.

[0084]

Thus, an image of the coelom wall illuminated by the respective illumination beams one after another is formed on the pick-up plane of the CCD 14 by the object optical system 13. The CCD 14 converts the image of the coelom wall into image signals and transmits the same to the initial stage signal processing circuit 223. The initial stage signal processing circuit 223 receives the image signals, holds only the image signals acquired when B light, G light or R light is emitted from the light distribution lens 12a, and abolishes the image signals acquired when white light is emitted.

[0085]

Subsequently, the initial stage signal processing circuit 223 carries out amplification and other signal processing with respect to the respective image signals held

thereby, and analog-digitally converts the image signals. Data obtained by the conversion are, respectively, stored in respective areas of B, G and R of the RGB memory 224. That is, if data is based on the image signals obtained when B light is emitted from the light distribution lens 12a, the data are stored in the B area of the RGB memory 224. With respect to the respective data based on the respective image signals obtained when the G light is emitted or B light is emitted, similar processing is carried out one after another.

[0086]

The picture signal processing circuit 225 generates color picture signals by acquiring and processing data in the RGB memory 224 at prescribed timing, and transmits the generated picture images to the video capture unit 226. The video capture unit 226 displays the acquired picture signals on the monitor 3 as a normal color image. In this state, the operator is able to observe (perform normal observation of) the surface of the coelom wall of a patient by looking at the monitor 3.

[0087]

Here, the operator changes over the switch of the operation portion and points out fluorescent observation, the CPU 221 detects the changeover and controls the light source

changeover controlling mechanism 214, wherein the changeover mirror 213 is changed to the fluorescent observation state, and the rotary filter controlling mechanism 216 is controlled to establish the rotary filter C in the fluorescent observation state. Then, the white light from the white light source 211 is interrupted, and pumping light from the pumping light source 212 is guided into the light guide 12b. Light guided into the light guide 12b is emitted from the light distribution lens 12a in the endoscope 1 and irradiates the coelom wall.

[0088]

The tissue on the surface of the coelom wall issues self-fluorescent light having a different wavelength (green light area) from that of pumping light when receiving the pumping light (ultraviolet area). Also, there is a feature in that self-fluorescent light that is generated at a tissue where a lesion such as a cancer and tumor, etc., occurs is weaker than self-fluorescent light generated at a sound tissue.

[0089]

The self-fluorescent light is made incident into the object optical system 13 along with the pumping light reflected by the coelom wall. However, the object optical system 13 interrupts the pumping light by the cut-off filter and permits only the self-fluorescent light to pass therethrough. And, the

object optical system 13 converges the self-fluorescent light on the pick-up plane of the CCD 14. Therefore, an image is formed on the pick-up plane of the CCD 14 by the self-fluorescent light.

[0090]

The CCD 14 converts the image into image signals and transmits the signals to the initial stage signal processing circuit 223. The initial stage processing circuit 223 receives the signals, carries out amplification and other processing with the corresponding image signals, and analog-digitally converts the signals. The data obtained by conversion are simultaneously written in all the areas of B, G and R of the RGB memory 224 (that is, processed as monochrome). The picture signal processing circuit 225 acquires and processes the data stored in the RGB memory 224 at a prescribed timing, generates monochrome picture signals, and transmits the generated picture signals to the video capture unit 226. The video capture unit 226 displays the acquired data on the monitor 3 as a fluorescent image. Also, the fluorescent image may be an image colored on the basis of the intensity, etc., of the self-fluorescent light.

[0091]

In this state, by observing the monitor 3, the operator

is able to observe (fluorescently observe) the state of the self-fluorescent light, which is produced on the coelom wall of a patient. And, the operator is able to distinguish that a portion where the self-fluorescent light is made weaker than that of the other portions is a portion having a high possibility of a lesion portion having a cancer or tumor formed.

[0092]

And, when the operator specifies a suspicious portion of lesion through the normal observation or fluorescent observation, he or she observes a tomogram of the portion and makes a diagnosis. That is, when the operator instructs tomogram pick-up by operating the operation portion of the endoscope 1, the CPU 221 controls the OCT portion 23, emits low coherent light from the SLD 231, and at the same time, controls the mirror drive mechanism 234 and scanning control circuit 235 to commence tomogram pickup.

[0093]

The scanning control circuit 235 rotates the polygon mirror 152 at an equal speed by driving the scanning motor (not illustrated) of the OCT scanning portion 15 in the endoscope 1. In the state shown in Fig. 3, the light emitted from the tip end of the optical fiber F1 is reflected by the reflection plane M1 of the polygon mirror 152 and is made incident into

the fθ lens 153. The fθ lens 153 converges the incident light above the coelom wall outward of the endoscope 1. At this time, since the polygon mirror 152 rotates at an equal speed, the light reflected by the reflection plane M1 scans at an equal speed above the scanning line hypothetically formed on the coelom wall.

[0094]

Further, since the polygon mirror 152 rotates, the light emitted from the tip end of the optical fiber F1 is made incident into the fθ lens 153 after being reflected by the next reflection plane M2. The fθ lens 153 converges the incident light on the coelom wall outward of the endoscope 1. The scanning line formed at this time shifts in parallel with prescribed spacing with respect to the scanning line formed by the reflection plane M1. After that, respective scanning lines corresponding to the respective reflection planes Mn further shift in parallel with prescribed spacing. Therefore, the respective scanning lines will be arranged on the coelom wall with equal spacing. That is, the rectangular area hypothetically covered up by the respective scanning lines will be swept one after another.

[0095]

At this time, the mirror drive mechanism 234 reciprocates

the reference mirror 233 in the axial direction of the optical fiber F2 at a high speed. Also, the mirror drive mechanism 234 and scanning control circuit 235 are synchronized by reference signals from the timing generator 222. That is, the reference mirror 234 makes a reciprocation at a high speed at every instant when the polygon mirror 152 is considered to stop, whereby, at a certain scanning point on a certain scanning line, an area from the surface of the coelom wall of the corresponding scanning point to a prescribed depth (for example, 2mm) that becomes an object to be measured is swept respectively.

[0096]

Also, in reality, scanning in the depth direction at respective scanning points is commenced from the position closer to the endoscope 1 than the surface of the coelom wall, and is carried out to a deeper position than the prescribed depth of the object to be measured. During the scanning, the OCT initial stage signal processing circuit 227 monitors output from the optical detector 232 at all times.

[0097]

At this time, the OCT initial stage signal processing circuit 227 does not detect any signal unless the measuring position in the depth direction at a certain scanning point reaches the surface of the coelom wall. However, it detects

signals as soon as the measuring position in the depth direction reaches the surface of the coelom wall. And, the OCT initial stage signal processing circuit 227 considers the depth, at which a signal is first detected at the corresponding scanning point, as the surface of the coelom wall, and carries out zero-point adjustment. That is, the OCT initial stage processing circuit 227 recognizes the depth, at which a signal is first detected, as the surface (depth: 0) of the coelom wall, and signals obtained in the range from the position to a prescribed depth (for example, 2mm deep) are made into the object to be measured.

[0098]

And, the OCT initial stage signal processing circuit 227 carries out amplification, demodulation, and A/D conversion with respect to the signals made into the object to be measured. Data obtained through the above-described processes are stored in the OCT memory 228. The OCT picture signal processing circuit 229 generates picture signals by acquiring the data stored in the OCT memory 228 at a prescribed timing and processing the same, and transmits the generated picture signals to the video capture unit 226. The video capture unit 226 displays the acquired data on the monitor 3. A tomogram from the surface of the coelom wall to a prescribed depth is displayed on the

monitor 3.

[0099]

Here, the tomogram on the monitor 3 is gradually renewed in synchronization with rotations of the polygon mirror 152 of the OCT scanning portion 15. That is, the tomogram displayed on the monitor 3 at a specified instant is a tomogram from the surface of the coelom wall to a prescribed depth at a scanning line corresponding to a certain reflection plane Mn. However, if the scanning line is displaced to a next position, the tomogram will be renewed. An operator is able to three-dimensionally recognize the state of a tissue below the surface of the coelom wall by continuously observing the tomogram while the polygon mirror 152 rotates once. Also, the video capture unit 226 is able to display in parallel the tomogram and an image brought about by normal observation or fluorescent observation on the monitor 3.

[0100]

The CPU 221 may gradually store the tomograms, which are consecutively acquired as described above, in a memory unit (not illustrated). When tomograms are thus stored, the CPU 221 is able to re-construct a three-dimensional cubic image of an analyte on the basis of the corresponding tomograms. The operator gives instructions to the CPU 221 through an input

unit 4, and is able to convert the re-constructed cubic image to a tomogram cut off along an optional plane and display the same on the monitor 3.

[0101]

Through such an observation, since the operator is able to recognize the state below or under the surface of the coelom wall, an accurate and quick diagnosis can be carried out. Also, the operator is able to detect an early cancer or a slight tumor, etc., by only an observation using the endoscope 1.

[0102]

Further, since an accurate and quick diagnosis is completed, the operator is able to give necessary treatment in response to the results of the diagnosis. That is, forceps or laser treating tools, etc., are taken out through a forceps-hole (not illustrated), which is opened at the tip end portion of the insertion portion of the endoscope 1, and various types of treatments can be carried out at that time. Therefore, burden of a patient can be relieved.

[0103]

In addition, as described above, since the OCT scanning portion 15 according to the embodiment includes a polygon mirror 15 which is able to scan two-dimensionally, no sub-scanning optical member is required. Also, in a prior art

regular prism polygon mirror, only a single-dimensional scanning with respect to a prescribed main scanning direction (the direction of the scanning line) is enabled, wherein a galvanomirror, etc., for reflecting light reflected by the polygon mirror was required to secure two-dimensional scanning. By shifting the scanning line to the sub-scanning direction perpendicular to the main scanning direction by the galvanomirror, etc., two-dimensional scanning is achieved for the first time.

[0104]

In the OCT scanning portion 15 according to the embodiment, since the sub-scanning optical member can be omitted while enabling the two-dimensional scanning, the embodiment can be made small-sized, wherein since the OCT scanning portion 15 is made small-sized, the insertion portion of the endoscope 1 can be also made small-sized, resulting in a decrease in the burden given to a patient.

[0105]

[Modified Version]

Hereinafter, a description is given of a modified version of the above-described embodiment. In the above-described embodiment, a polygon mirror 152 formed to use a hexagonal prism as a reference is used. On the contrary, as shown in Fig. 8,

a polygon mirror formed to use a hexagonal cone H′ as a reference is used in the present modified version. Also, all the other constructions are identical to those of the above-described embodiment.

[0106]

The hexagonal cone H′ that becomes a reference is formed so that the bottom plane thereof is regularly hexagonal, and the respective sides thereof are identical to each other and are of a trapezoidal shape with equal legs. The polygon mirror according to the modified version has six reflection planes Mn′, and the respective reflection planes Mn′ are made coincident with planes formed by being rotated and displaced by a prescribed angle (inclination angle) ξn′ centering around an axis R′ perpendicular to the center axis of the hexagonal cone H′ on the reference side plane where the respective sides of the hexagonal cone H′ are made into the reference sides. Also, the values of ξn′ respectively differ from each other per reflection plane Mn′.

[0107]

By using the polygon mirror thus formed, actions and effects similar to those in the above-described embodiment can be brought about.

[0108]

[Effects of the Invention]

According to a polygon mirror of the invention and a scanning optical system thereof, which are constructed as described above, a two-dimensional area can be scanned with a simplified structure.

[0109]

Also, according to an endoscope apparatus of the invention, a tomogram regarding a three-dimensional area from the corresponding analyte surface in a prescribed two-dimensional area on the analyte to a specified depth can be obtained. Therefore, where any lesion exists below or under the surface of the analyte, an operator is able to accurately and quickly specify the corresponding lesion.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] is a rough configuration view of an endoscope according to one embodiment of the invention;

[Fig. 2] is an exemplary view showing an optical path of the OCT portion;

[Fig. 3] is a configurational view of the OCT scanning portion according to the embodiment of the invention;

[Fig. 4] is a sectional view taken along the line IV-IV in Fig. 3;

[Fig. 5] is a view observed in the direction of the arrow

in Fig. 3;

[Fig. 6] is an exemplary view showing the profile of a polygon mirror according to the embodiment of the invention;

[Fig. 7] is a view showing an inclination angle of the reflection planes of the polygon mirror according to the embodiment of the invention; and

[Fig. 8] is an exemplary view showing the profile of a polygon mirror according to the modified version.

[Description of Symbols]

1	Endoscope apparatus
12	Illumination optical system
13	Object optical system
14	CCD
15	OCT scanning portion
152	Polygon mirror
Mn	Reflection plane
ξn	Inclination plane
153	$f\theta$ lens
2	Peripheral apparatus
21	Light source portion
211	White light source
212	Pumping light source
213	Changeover mirror

214	Light source changeover controlling mechanism
22	Processor
227	OCT initial stage signal processing circuit
23	OCT portion
231	Low coherent light source
232	Optical detector
233	Reference mirror
234	Mirror drive mechanism
235	Scanning control circuit
238	Optical coupler
F1	First waveguide
F2	Second waveguide
3	Monitor

[TITLE OF DOCUMENT] Abstract

[ABSTRACT]

[Theme] To provide an endoscope apparatus that can bring about a tomogram by the OCT.

[Solution means] The OCT portion 23 of the endoscope apparatus includes a first optical fiber F1 opposed to the base end of the SLD 231, a second optical fiber F2 whose base end is opposed to the optical detector 232, an optical coupler 238 for optically connecting the optical fibers to each other, and a displaceable reference mirror 233 disposed at the tip end of the second optical fiber F2. And, the tip end of the first optical fiber F1 is guided by the OCT scanning portion 15 at the tip end of the endoscope 1. The OCT scanning portion 15 includes a polygon mirror 152 whose respective reflection planes Mn are, respectively, inclined at angles differing from each other, and forms a plurality of scanning lines juxtaposed on an analyte with equal spacing therebetween. In addition, the OCT scanning portion 15 emits light, which is emitted from the tip end of the first optical fiber F1, to an analyte, and at the same time, guides the light reflected by the analyte to the first optical fiber F1.

[SELECTIVE DRAWING] Fig. 3

Fig.1

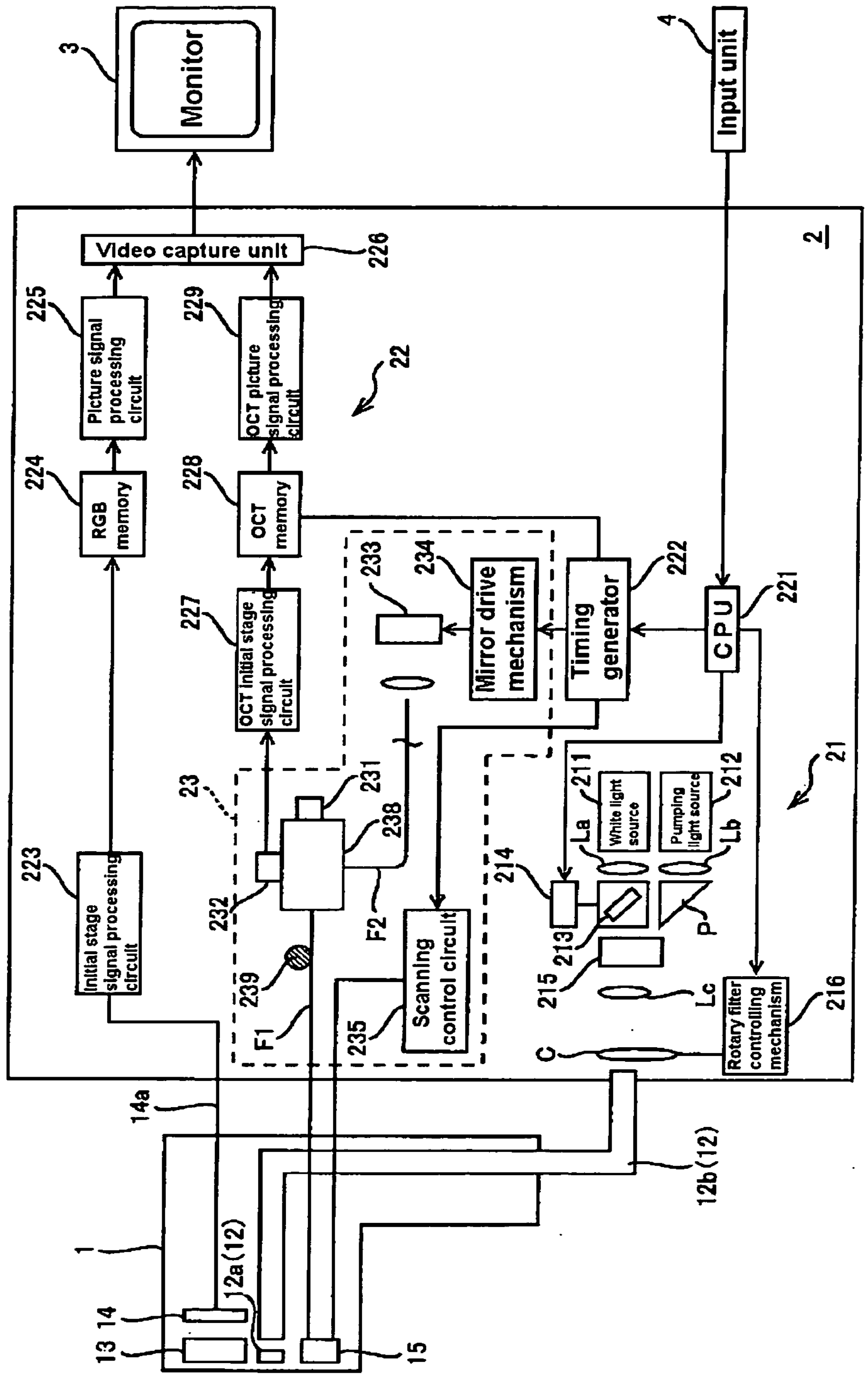
Monitor
3
Input unit
4
Video capture unit
226
2
225
Picture signal processing circuit
229
OCT picture signal processing circuit
22
224
RGB memory
228
OCT memory
233
234
Mirror drive mechanism
Timing generator
222
CPU
221
227
OCT initial stage signal processing circuit
23
231
238
232
223
Initial stage signal processing circuit
239
F1
F2
235
Scanning control circuit
211
White light source
212
Pumping light source
21
La
Lb
214
213
P
215
Lc
C
Rotary filter controlling mechanism
216
14a
12b (12)
1
12a (12)
13
14
15

Fig.2

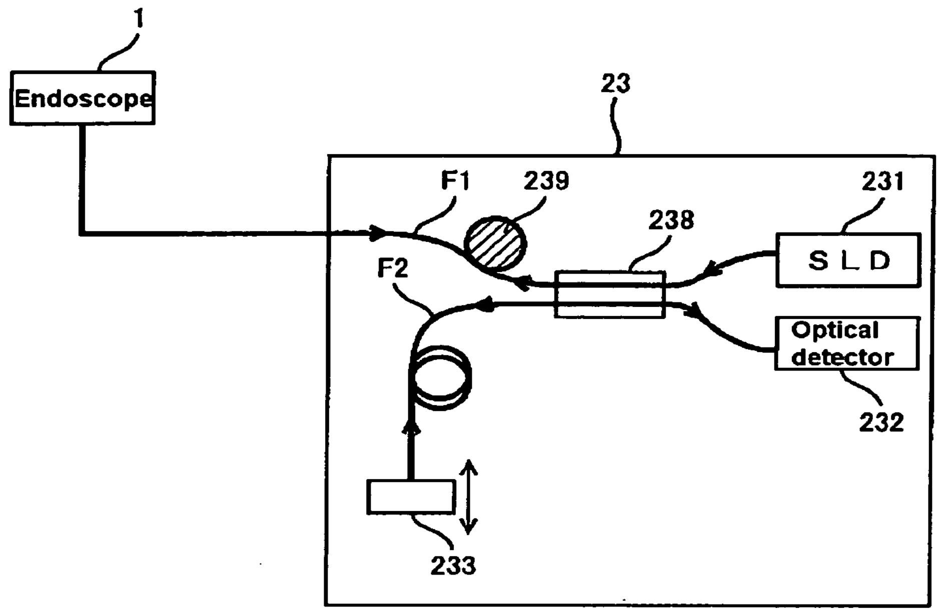
1
Endoscope
23
F1
239
231
238
SLD
F2
Optical detector
232
233

Fig.3

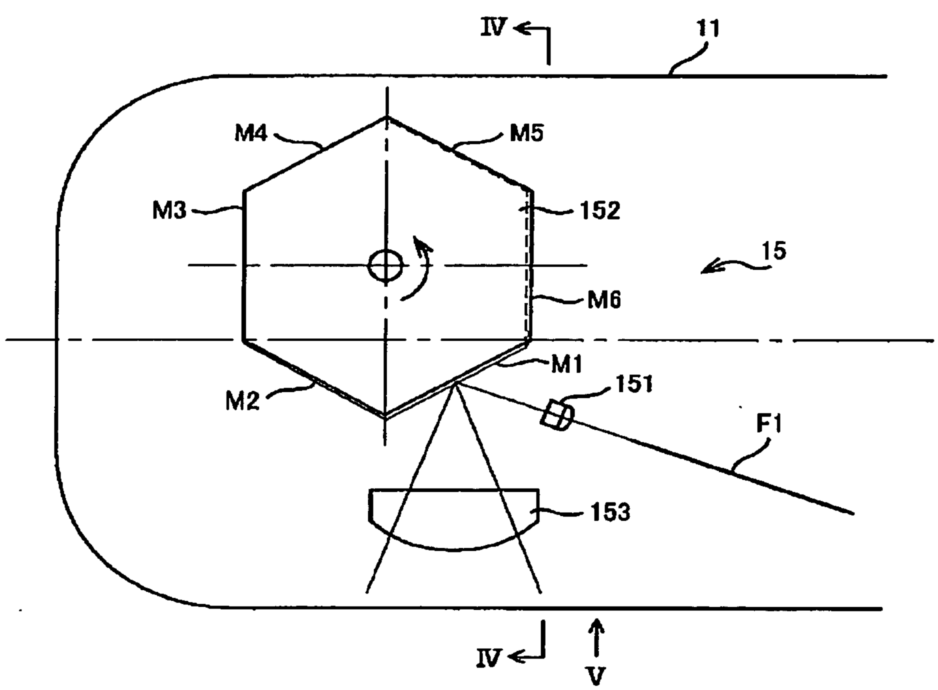
IV
11
M4
M5
M3
152
15
M6
M1
151
M2
F1
153
IV
V

Fig.4

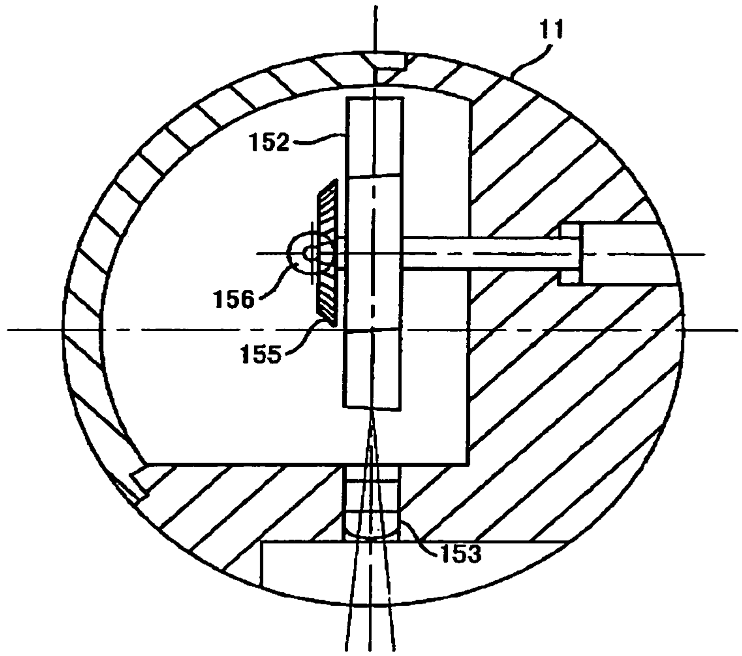

Fig.5

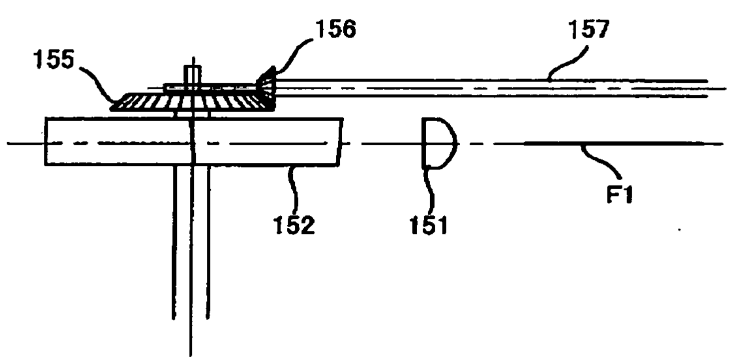

Fig.6

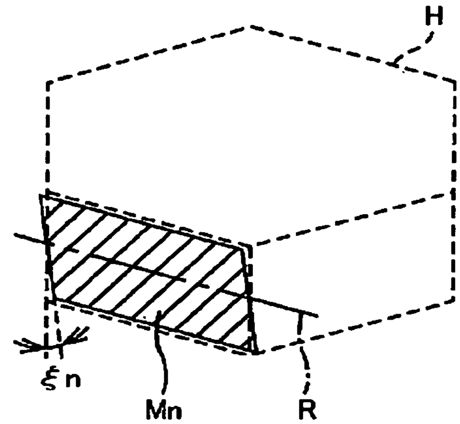

Fig.7

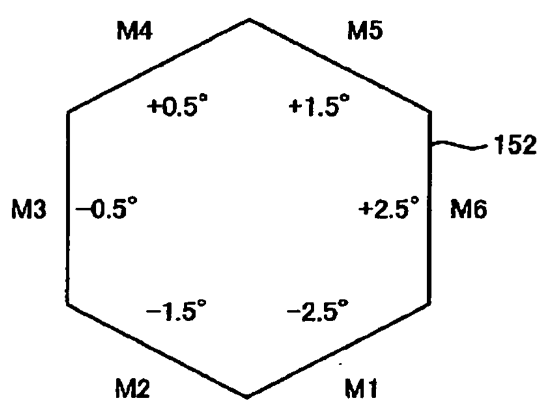

Fig.8